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EFFECT OF PROCESSED SPENT BLEACHING EARTH ON COMPRESSIVE STRENGTH AND TENSILE SPLITTING STRENGTH OF FOAMED CONCRETE

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B. ENG(HONS.) CIVIL ENGINEERING

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MOHD SHARIFF BIN RAZAK

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ABSTRAK

Konkrit berbusa adalah sejenis konkrit ringan yang mempunyai kebolehkerjaan yang baik dan tidak memerlukan proses pemadatan. Umumnya, ia mengakui konkrit berbuih sebagai bahan binaan dengan kekuatan dan kelemahan yang rendah, terutamanya apabila bahan binaan tertakluk kepada tenaga impak yang tinggi. Walau bagaimanapun, konkrit berbusa adalah bahan yang berpotensi untuk membina konsep futuristik. Pembinaan futuristik adalah pembinaan bangunan yang ringan, ekonomi dan mudah dan yang paling penting adalah mesra alam. Dalam kajian ini, simen telah digantikan oleh Spent Bleaching Earth Processing (PSBE) dalam peratusan tertentu konkrit untuk menilai kekuatannya. Peratusan peratus PSBE yang digunakan adalah 10%, 20% dan 30% dengan ketumpatan buih 1600 kg/m^3. Untuk menentukan nilai kekuatan mampatan dan nilai kekuatan pemisahan tegangan tekanan tegangan eksperimen, 36 kiub dan 36 silinder sampel disediakan. Ujian mampatan dan ujian pemisahan tegangan dilakukan pada sampel untuk umur sembuh 28, 60, dan 90 hari. Telah dinyatakan bahawa kekuatan konkrit berbusa menggunakan PSBE sebagai pengganti simen separa jelas meningkat dengan peningkatan peratusan PSBE sebagai pengganti simen. Hasil menunjukkan bahawa 30% PSBE sebagai pengganti simen separa menunjukkan kekuatan tertinggi iaitu 16.08 MPa untuk ujian mampatan dan 17.46 MPa untuk uji pemisahan tegangan. Secara keseluruhannya, penemuan utama bagi kedua-dua eksperimen ini menunjukkan bahawa kenaikan peratusan PSBE meningkatkan kekuatan konkrit berbusa.

ABSTRACT

Foamed concrete is a kind of lightweight concrete that has good workability and does not require compaction process. Generally, it recognizes foaming concrete as building materials with low strengths and weaknesses, especially when the building materials are subject to high impact energy. However, foaming concrete is a potential material for building futuristic concepts. Futuristic construction is a light, economical and easy building construction and most importantly is environmentally friendly. In this study, cement was replaced by Spent Bleaching Earth Processing (PSBE) in a certain percentage of concrete to assess its strengths. Percentage of PSBE percentage used is 10%, 20% and 30% with foam density 1600kg / m3. To determine the value of the compressive strength and the value of tensile splitting strength of the experimental pressure tensile, 36 cube and 36 cylinder samples was prepared. Compression testing and tensile splitting test was performed on the sample for 28, 60, and 90 days curing age. It has been specified that the strength of foamed concrete using PSBE as partial cement replacement clearly increased with the increase of the percentage of PSBE as cement replacement. Result exhibit that 30% PSBE as partial cement replacement shows the highest strength which is 16.08 MPa for compressive test and 17.46 MPa for tensile splitting test. Overall, the major findings for both experiments show that increment of PSBE percentage increase the foamed concrete strength.

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LIST OF ABBREVIATIONS

PSBE	Processed spent bleaching earth
FC	Foamed conrete
ASTM	American Society for Testing and Materials
FKASA	Fakulti Kejuruteraan Awam
UMP	Universiti Malaysia Pahang
SBE	Spent bleaching earth
C-S-H	Calcium silicate hydrate
CO_2	Carbon Dioxide

CHAPTER 1

INTRODUCTION

1.1 Background Study

Foamed concrete is known as cellular concrete or cellular materials for the availability of air cavities in this construction material (Zahari, Rahman and A Mujahid A Zaidi, 2009). Cellular material was found to have impact resistance properties better than ordinary concrete building materials (Jones and McCarthy, 2005). The foamed concrete potentially be used as an alternative material for structures that emphasize features impact resistance in its construction. Property belonging impact resistance foamed concrete there is a relationship with the base material used for and forming the composite base material used is cement, sand, water and foam(Ramamurthy, Kunhanandan Nambiar and Indu Siva Ranjani, 2009).

Foam material used to make foamed concrete varies with the establishment of concrete ordinary. The foam material has resulted in a foamed concrete hollow cavity air and at the same time improving its impact resistance foamed concrete (Zahari, Rahman and A Mujahid A Zaidi, 2009). In addition, the aggregates are not used in the formation of foamed concrete. Thus, foamed concrete has a lower density than ordinary concrete. In addition, the foamed concrete has good workability and very easy run (Jones and McCarthy, 2005). This is because the warning is not used to foamed concrete levelling fresh.

In summary foamed concrete has many goodness for the construction of the futuristic structure that is characterized by lightness, economy, simple in terms of construction work, and most importantly environmentally friendly (Jones and McCarthy, 2005). However, foamed concrete is applied as construction materials due to the composite structure have its drawbacks, namely fragile.

1.2 Problem Statement

Every year, climate change becomes more and more issues. When all greenhouse gas emissions generated by human activities are considered, the cement industry is responsible for approximately 3% of global emissions. In terms of CO_2, the cement industry contributes about 5% to global anthropogenic emissions (Madeleine Rubenstein, 2012). The estimated total carbon emissions from cement production in 1994 were 307 million metric tons of carbon (MtC); 160 MtC from process carbon emissions, and 147 MtC from energy use. Overall, the top 10 cement-producing countries in 1994 accounted for 63% of global CO_2 emissions from cement production (Sidek, 2016).

Currently, abundant wastes from the palm oil refining process have been generated which are hard to handle. Processed Spent Bleaching Earth (PSBE) is the solid waste from this process and leads the cost of elimination to the company. PSBE also present fire hazard in spontaneous combustion because it possesses the pyrogenic nature due to the instauration of the fatty acids in the retained oils. The waste is commonly disposed to landfill without any pretreatment. From the environmental, safe and regulatory points of view, it is urgent to restrict the landfill practice in the future (Muguntan Vanar, 2013).

1.3 Objectives

This study is to achieve the following objectives:

i. To investigate the compressive strength of foamed concrete mixture containing 0 to 30% PSBE as partial cement replacement.
ii. To investigate the tensile splitting strength of the foamed concrete mixtures containing 0 to 30% PSBE as partial cement replacement.

1.4 Scope of Work

The scope of this study focuses on the development of lightweight foamed concrete for use as a building material and structural materials in the construction industry. Selection of raw materials that are readily available industrial surplus on the market seeks to maximize the use of these materials. It also aimed to evaluate the capabilities and performance of lightweight foamed concrete of the properties of engineering materials, namely the strength and resilience that will be generated. The study also focused on producing lightweight foamed concrete mix design the most suitable mix design through a series of laboratory experiments and tests. The mix design focus and emphasis on the properties of the foam, the ratio of cement, silica sand, and water-cement ratio to produce concrete lightweight foamed in accordance with its function as a building material. Curing method in water was use for the resulting foamed lightweight concrete.

1.5 Significance of Study

Reviews for producing concrete products that meet consumers' needs should continue and enhanced. The focus should be given to the use of various raw materials to produce lightweight foamed concrete that has the characteristics strength and improved durability in addition to the characteristics of a good insulator. In efforts to protect the environment and reduce the use of raw material resources, the use of the surplus and the rest of the industry should be enhanced.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Revolution of industry has brought a lot of improvement to research and development related to materials of concrete. These developments have been facilitated by increased knowledge of the atomic and molecular structure of materials, development of more powerful instrumentation and monitoring techniques, studies of long-term failures, decreases in the cost-effectiveness of traditional materials, and the need for stronger and better performing materials suitable for larger structures and longer spans, as well as for increased ductility. Nawy states that in 21^{st} century people will see the emergence of high-strength, high-performance concrete, particularly in the world infrastructure of roads, buildings, and bridges (Swamy, 2008)

2.2 Introduction of foamed concrete

Foamed concrete is quite simply mortar with lots of air bubbles in. In fact it is not actually concrete at all and contains no aggregates, so does not offer the same characteristics. The air content is generally between 50% and 75% by volume which makes it a very lightweight and easily free flowing material. It has a range of unique features that make it the ideal solutions for a variety of applications.

Foamed concrete is easy to place, pour or pump to the required location, it does not need to be compacted or vibrated/levelled, it is resistant to frost, water and cracking, and provides great sound and heat insulation. Foamed concrete can be made using a range of different mix designs to suit different purposes and so it almost always needs to be mixed on site to suit the job at hand.

2.3 Application of foamed concrete

The most widespread use of foamed concrete in India is for making pre-cast lightweight blocks. These blocks are used to construct non-structural walls in apartments, hotels and offices. Foamed concrete is lightweight which means that the loading on the building is reduced. Therefore the amount of structural steelwork and structural concrete is also reduced resulting in significant cost savings. The thermal insulation properties of foamed concrete mean that there will be greater comfort and reduced air-conditioning and heating costs for tenants.

Foamed concrete does not shrink, is free flowing and fills every gap, even beneath overhangs. It can be placed quickly in large quantities through narrow openings, which means void filling can be tackled with minimal disruption. Both planned and emergency void filling are regularly carried out using foamed concrete. In Lublin, Poland, foamed concrete was used to stabilise the ground in an emergency situation. A recently constructed roadway built over a previously inadequately compacted trench reinstatement was in danger of collapse when heavy rains washed away the ground beneath it. A large void was created under the roadway which remained suspended in mid air over a distance of 30 metres. Using traditional methods, the repair would have taken three weeks to be completed, including the dismantling and re-assembly of the road structure, which consisted of pavers bedded in mortar. Using foamed concrete, the whole job was completed and the road re-opened in 48 hours.

When roads are built over soft ground, they often begin to sink in a non-uniform manner creating an uneven and broken road surface. By excavating the soft ground and replacing it with foamed concrete that is less dense, a floating road sub-base can be built. This stops the road from sinking and has been used for building roads in Holland. Using foamed concrete for road sub-bases can reduce the cost of foundations. The re-development of Canary Wharf, in the docklands area of London, saw the use of 27,000 m3 of foamed concrete for a lightweight road sub-base. Here the cost of the pile foundation was reduced by a factor of three by using foamed concrete instead of sand.

Foamed concrete saves on the use of other materials. It directly saves on material usage since it can be made using fly ash, which is a bi-product of energy generation. Indirectly, since it is lightweight and does not impose large loadings, it reduces the amount steel work and structural concrete required in building construction and civil engineering projects. The most obvious environmental benefit of foamed concrete is its ability to provide thermal insulation.

2.4 Foamed concrete material

Concrete can be produced by three basis components which is cement, water and aggregates. The important thing to know is how to determine the ratio of the composition when produced a good concrete. For the reasons to produce good concrete is long term used when the material are mixed together. If the designs of the structure are safe to used, there are no use if the production of the material cannot be fulfilled the specification needed. So there are important the basis of the concrete production with the material used to produce good result in terms of time.

2.4.1 Cement

Cement is the most commonly used binding agent. Other binder materials like quarry dust and fly ash can also be used in conjunction with cement. The quarry dust can be used as an additional filler material. Quarry dust consists mainly of excess fines generated from crushing, washing and screening operations at quarries. The material properties of this waste, vary with the source, but are relatively constant at a particular site. A good fly ash should have high fineness, low carbon content and good reactivity, which would enhance the technical advantage to the properties of foamed concrete.(Jalal *et al.*, 2017)

2.4.2 Sand

Sand is a major component in concrete mixes. Sand from natural gravel deposits or crushed rocks is a suitable material used as a fine aggregate in concrete production. It is used with coarse aggregates to produce a structural concrete and can be also used alone with cement for mortars and plastering works. It is also economical since it is abundant near most construction works (Al-Harthy *et al.*, 2007).

2.4.3 Water

In a production of concrete, water plays an important role. It is used in many purpose such as wash aggregates, as a mixing water, during the curing process and to wash out mixers. When the aggregate are coated by the silt, salts, or organic materials, the aggregates must be cleaned and wash out by the water. This to avoid the aggregate and the water may produce distress concrete due to chemical reaction with the cement paste or poor aggregates bonding. The water also important because it will affect volume stability and cause the leaching of free lime, discoloration and excessive reinforcement corrosion. The salts of manganese, tin, zinc, cooper, and lead may cause reduction in strength and variations in setting times. The use of water containing acids or organic substances should be questioned because of the possibility of surface reactions and retardation(Kucche, Jamkar and Sadgir, 2015).

2.4.4 Processed Spent Bleaching Earth

Processed Spent bleaching earth (PSBE) is an industrial waste, mainly generated from the edible oil processing (Z. Werner 1994). It is noted that PSBE can present a fire hazard (i.e. spontaneous combustion), because it usually contains 20-40% oil by weight (Tee, 2010). These oils retained and not removed by filter pressing may possess the pyrogenic nature due to the instauration. Currently, world production of edible oil and fat industries amounts reaching to more than 65 million tons and production of PSBE is estimated at 650,000 tons worldwide (Park, Kato and Ming, 2004).

2.4.4.1 Properties of Spent Bleaching Earth

Figure 2.4.1The features of fresh bleaching earth (A), Spent bleaching earth (B), and Reactivated bleaching earth (C)

After its use, bleaching earth may be loaded with a number of various materials besides oil. For that reason, further utilization of the earth will depend on the kind of absorbed impurities with consideration of ecological as well as economical aspects. This spent bleaching earth is susceptible to spontaneous combustion; consequently, there are few practical uses for it, and handling and disposing of spent bleaching earth is a fire risk, an operating expense, and a source of environmental regulatory concerns not to mention a significant cost due to the value of the oil that is lost (Norman J. Smallwood, 2015)

2.4.4.2 Disposal of Spent Bleaching Earth

Since the advent of using clay to adsorb color pigments and impurities from edible oil, processors have been confronted with the problem of spent earth disposal. Typically, spent bleaching earth contains entrained oil in the range of 30 to 50% by weight. The entrained oil is in the form of a thin film spread over the immense surface area provided by the clay particles. Upon exposure to air, rapid oxidation of the oil film occurs and sufficient heat is generated to cause spontaneous combustion. Consequently, the most common method of spent earth disposal is to haul and bury it at a solid waste disposal site. Handling and disposing of spent earth is a fire risk, an operating expense, and a source of environmental regulatory concerns. In addition, the value of the oil that is lost is a significant cost.

2.4.5 Compressive Strength of Foamed Concrete

Compressive strength of foamed concrete has a direct relationship with density where a reduction in density exponentially and adversely affects the compressive strength.

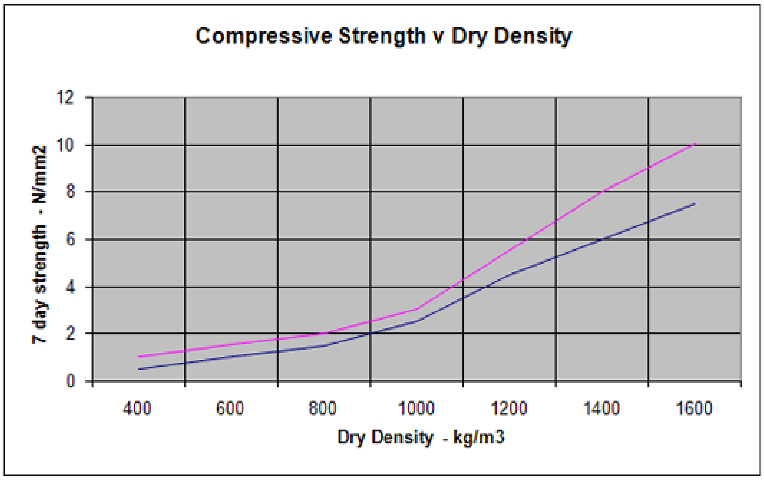

Figure 2.4.5 Dry density against strength graph

In general, compressive strength depends on different parameters such as rate of foam agent, w/c ratio, sand particle type, the curing method, cement–sand ratio, and characteristics of additional ingredients and their distribution. One of the major controlling factors in compressive strength of the mix is the volume/density of foam agent by which the amount of air-voids in the hardened foamed concrete varies.

Water/cement ratio is another controlling factor which influences the compressive strength of the foamed concrete. Appropriate content of water enhances the consistency and stability of the mix and reduces the large size foam bubbles which increases the compressive strength.

Next, cement replacements such as silica fume and fly ash change the compressive strength value of the mix in the course of time. High volume replacement of up to 65% was reported in foamed concrete by usage of fly ash with no reduction in strength. For silica fume, the reported replacement was lower in content, albeit, the strength gain in long run was enhanced due to its pozzolanic behavior. The application of binary mix of silica fume and fly ash, reportedly, increased the compressive strength up to 25% (Thomas, 2007).

2.4.6 Tensile Splitting Strength

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete.

The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.

In foamed concrete, the tensile strength is lower than that of normal concrete. In general, it is reported that the ratio of tensile strength to compressive strength of foamed concrete ranges between 0.2 and 0.4 which is higher compared to normal concrete that possesses a ratio of splitting tensile to compressive strengths between 0.08 and 0.11 (Othuman Mydin, 2016).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This section discusses on the selection of materials, mix proportion of concrete containing the waste clay brick, specimen preparation and testing methods to achieve the objectives of this study. The early part of this chapter discusses about materials used to produce concrete specimen for this study namely, ordinary portland cement, PSBE, silica sand, foam, and water. Then, the discussion moved on elaboration issues related to process of preparation the concrete mix proportion as well as sample preparation process. The procedure of testing followed to determine the compressive strength, and tensile splitting strength.

3.2 Experiment Flow Process

The flow throughout this study will be conducted as shown in Figure 3.2.

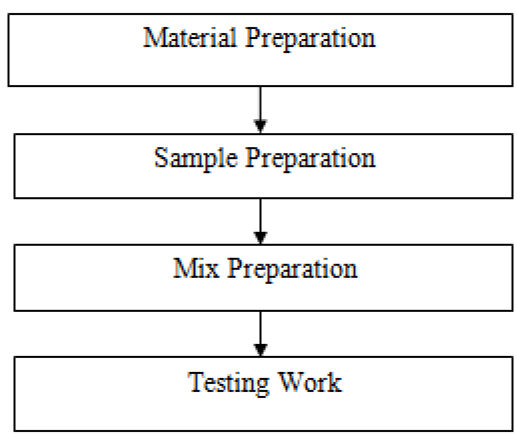

Figure 3.2 Experiment process flow

3.3 Material Preparation

Before casting, each of the material that is needed for this study was prepared to obtain the best condition and to ensure that the result that will be produced is valid.

3.3.1 Ordinary Portland Cement

ORANG KUAT Ordinary Portland Cement Brand (OPC) produced by YTL Cement Marketing Sdn Bhd was used throughout this research in order to ensure that the cement has the same chemical properties and chemical compositions. This type of cement was following the Malaysian Standard MS 522: Part 1: 2007 for Portland cement specification. This type of cement is suitable for structural concreting, precast, and all general purpose applications. All of the cements was stored away from damp floor and stacked together in a dry location, clean and well-aired. Figure 3.2 show the ordinary Portland cement that will be used.

Figure 3.3.1 Ordinary Portland Cement

3.3.2 Spent Bleaching Earth

Figure 3.3.2 Processed Spent Bleaching Earth(PSBE)

PSBE was dried in the oven for 24 hours to remove water content so that water cement ratio is not miscalculated. Then the PSBE was sieved until passing 300µm. Weight of PSBE needed in this study was taken.

3.3.3 Foaming Agent

A chemical which facilities the process of forming foam and enables it with the ability to support its integrity by giving strength to each single bubble of foam is known as foaming agent. It may categorize in two parts Protein and Synthetic.

Protein based is commonly used for the low density and for higher densities synthetic foaming agents were preferred. Foam can create through forcing the chemical, air and water by restriction which results foam formation. Synthetic foam requires less energy while protein foams need more. Energy required during the foam formation decides its quality.

Figure 3.3.3 Foaming agent

3.3.4 Silica Sand

Figure 3.3.4 Silica sand

Silica Sand was dried in the oven for 24 hours to remove water content so that water cement ratio is not miscalculated. Then the PSBE will be sieved until passing 300µm. Weight of PSBE needed in this study was taken.

3.3.5 Water

Water played the major roles in the concrete production. The presence of water in concrete mixing is to promote hydration. Water also facilitates mixing placing and compacting of the fresh concrete and also for curing process of concrete. Water must be clean from impurities. Tap water was used in this research because impure water can have adverse effect to the strength of the concrete.

3.4 Specimen Preparation

Samples for this experiment are provided based on the mix designs were prepared. Concrete mix made for the one samples base on experimental sample using 10%, 20% and 30% PSBE as partial cement replacement. The result for all samples was compared with the normal concrete. Therefore, all experimental result was determined whether it is better or not.

3.5 Testing Method

3.5.1 Compressive Strength

The compressive strength of the specimen was tested according to BS EN 1881:116 (Method for determination of compressive strength of concrete cubes). Specimens was loaded to failure in a compression testing machine. All the specimens were cured in the water tank for 28, 60, and 90 days before tests for its compressive strength. The maximum load sustained by the specimen is recorded and the compressive strength of the concrete was calculated. The compressive strength is given by the Eq. where σ is the compressive strength in Megapascal (MPa). P is the maximum load that failure, in Newton and Ac is from the cross-sectional area of the specimen on which the compressive force acted, calculated from the designated size of the specimen or from measurements on the specimen if testes according to Annex B, in mm^2. The compressive strength shall be expressed to the nearest 0.1 MPa (N/mm2), 3 samples was prepared for each test. The compressive strength of the cubes was calculated with Equation 3.5.1.

Figure 3.5.1 Compressive strength test

$$\partial = \frac{P}{A_c} \qquad 3.5.1$$

Where:

σ = Compressive strength (MPa)

P = Force applied (N)

A_c = Area of specimen (mm²)

3.5.2 Tensile Splitting Strength

For splitting tensile test, 36 cylinder shape specimen with 100 diameter and 200 in height was used. This test conducted using BS EN 12390-6:2000 (Tensile splitting strength of test specimens). After curing, specimen was wiped to remove excess water. Each part of the testing machine then was cleaned to remove any loose sand or grit and other extraneous material from the surface of the specimen that will be in contact with the packing strips.

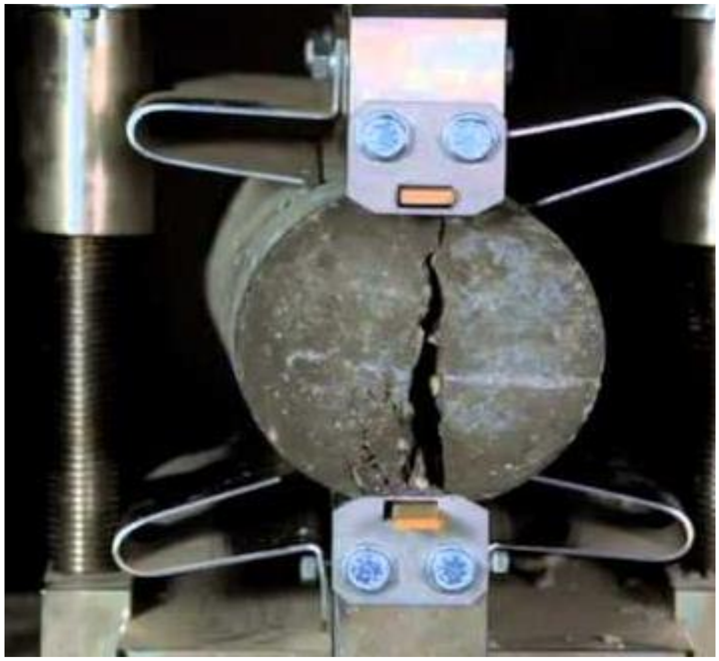

Figure 3.5.2 Tensile splitting strength test

Below is the testing procedure for tensile splitting testing:

i. Diametrical line on the two ends of the specimen was drawn to ensure that they are on the same axial place.

ii. The weight and dimension of the specimen was noted.

iii. The compression testing machine was set for the required range.

iv. The specimen was aligned so that the lines marked on the ends are vertical and centred over the bottom plate.

v. The upper plate was brought down to touch the cylinder holder.

vi. The load was applied continuously without shock at a rate of approximately 14-21kg/cm2/minute (Which corresponds to a total load of 9900kg/minute to 14850kg/minute)

vii. The breaking load (P) was noted down.

Then the calculation tensile splitting strength was conducted using equation 3.3.

$$\boldsymbol{F_{ct}} = \frac{\boldsymbol{2 \times F}}{\boldsymbol{\pi \times L \times D}} \qquad 3.5.2$$

Where :

F_{ct} = Tensile splitting strength, in mega pascal or newtons per square millimetre;

F = Maximum load, in newtons;

L = Length of the line of contact of the specimen, in millimetres;

D = Designated cross-sectional dimension, in millimetres.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Present research studies the effect of Processed Spent Bleaching Earth (PSBE) on the foamed concrete strength and tensile strength as partial cement replacement. There are four mixtures of foamed concrete were prepared such as 0% of PSBE as control sample,10%, 20% and 30% of PSBE as partial cement replacement. All specimens was tested to determine the compressive and tensile strength of foamed concrete.

4.2 Effect of PSBE as Cement Replacement on Compressive Strength of Foamed Concrete

The compressive strength of control foamed concrete mixes was compared to different proportions of PSBE at control, 10%, 20% and 30%. From Figure 4.2, it shows that at all consecutive day, the compressive strengths of 10%, 20% and 30% PSBE was found to be higher than control foamed concrete. For 30% PSBE, the compressive strength was recorded to be highest compared to that of the control mix. It can be seen from Figure 1 that 10% PSBE presented the lowest compressive strength than 20% and 30%. This results show that PSBE have high pozzolanic content. High compressive strength are obtained from the high rate of reaction that increase the hydration process within the mixture means that PSBE have high content of calcium silicate hydrate (C-S-H gel). In addition, the compressive strength of foamed concrete increase because of increasing value of density of the concrete.

Table 4.2.1 Compressive strength of foamed concrete

	Compressive Strength (MPa)			
Days	**0% PSBE**	**10% PSBE**	**20% PSBE**	**30% PSBE**
28	1.57	7.52	9.43	13.31
60	1.78	7.77	9.75	14.90
90	2.22	8.31	10.76	16.08

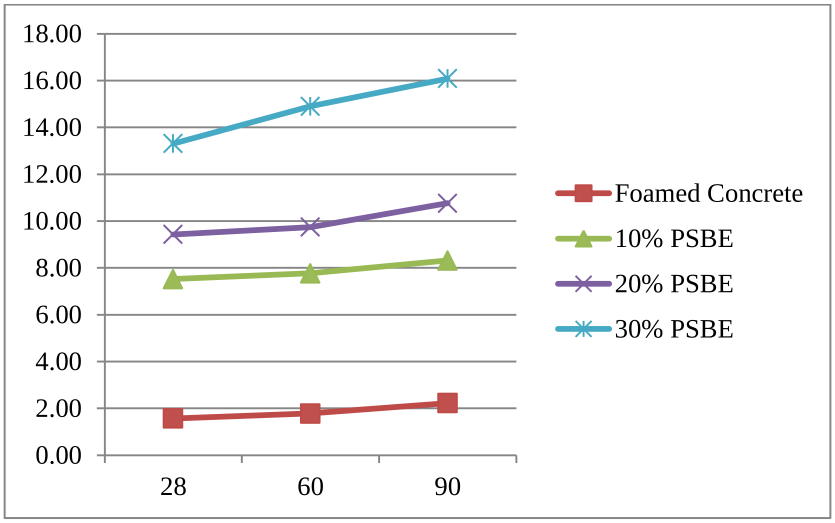

Figure 4.2.1 Compressive strength result

4.3 Effect of PSBE as Cement Replacement on Tensile Splitting Strength of Foamed Concrete

The trends observed in the splitting tensile strength of the 0%, 10%, 20%, 30% PSBE were used to compare the strength of the sample. Observations were made throughout the duration of the 28, 60, and 90 days. The splitting tensile strength of the specimens with 30% of PSBE as partial cement replacement was found to be significantly higher that other specimen. Highest tensile splitting strength by plain foamed concrete was 2.22 MPa while 30% of PSBE content as partial cement replacement achieved enormous 16.08 MPa. The high tensile strength achieved due to the high pozzolanic reaction rate in the mixture.

Table 4.3.1 Tensile splitting strength result

	Compressive Strength (MPa)			
Days	**0% PSBE**	**10% PSBE**	**20% PSBE**	**30% PSBE**
28	1.42	6.55	8.61	15.16
60	1.70	6.74	9.66	16.69
90	2.07	7.17	10.81	17.46

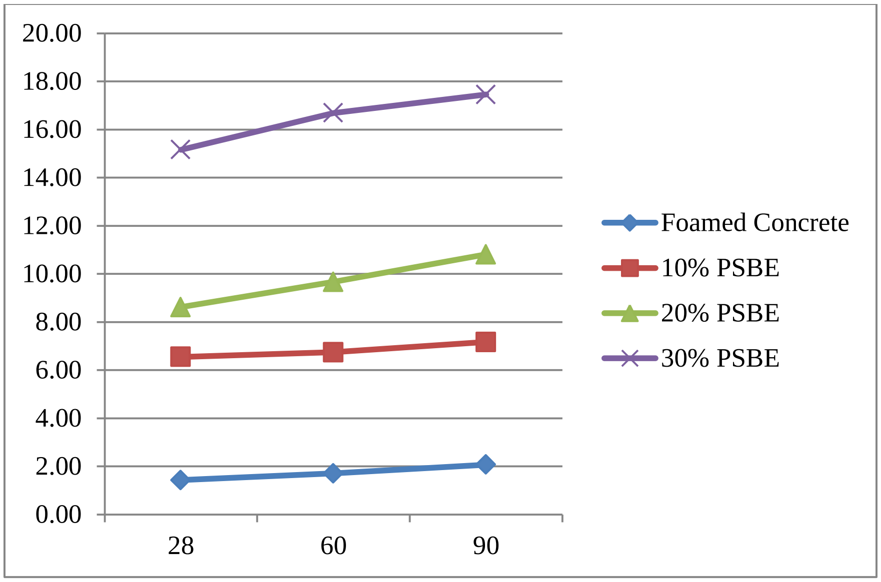

Figure 4.3.1 Tensile splitting strength of foamed concrete

CHAPTER 5

CONCLUSION

5.1 Introduction

Referring both testing results, it can be concluded that using PSBE as partial cement replacement does improve the foamed concrete performance. This research described that PSBE can be used as partial cement replacement without affecting its strength. By utilizing PSBE, we can reduce the production of cement while reducing the negative substance emitted by cement making industry.

5.2 Conclusion

This study reviewed all the processes from the primary stages of foamed concrete mix design up to the analysis of obtained data. Experimental laboratory works were carried out to obtain data for compressive strength and splitting tensile strength. Results from tests indicate that the compressive strength of foamed concrete increased sharply by increasing percentage of cement replaced by PSBE. Essentially, it can be concluded that replacing high proportions of cement with PSBE does significantly affect the long-term compressive strength of well-cured foamed concrete. Results also show that this strength was observed in all samples, although foamed concrete mixtures with PSBE content may require a longer period to reach their ultimate strength. Similar research on PSBE has also indicated that the cost of foamed concrete mixtures could be reduced by replacing large volumes of cement without significantly affecting the long-term strength. Improvement in the compressive and splitting tensile strength of foamed concrete with the use of PSBE is due to the higher rate of reaction between the minerals in the silica fume with foam concrete.

5.3 Recommendation

The research have proved that using PSBE as partial cement replacement improve the foamed concrete performance. By practicing the mixture, less amount of cement can be used which is brought to reduction of cost and more importantly, carbon dioxide emission that lead to environmental pollution can also be reduced. But, further research need to be conducted to specify others characteristic that PSBE content.

a. It is recommended to conduct a series of investigation on variety of density value by using PSBE as partial cement replacement.

b. It is recommended to conduct a series of investigation on the suitable percentage of PSBE as partial cement replacement that can be used in real construction situation.

c. It is recommended to conduct a series of investigation on the durability of the foamed concrete using PSBE as partial cement replacement such as, carbonation test, acid attack test, and permeability test.

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APPENDICES

LABORATORY TESTING RESULT

	COMPRESSIVE STRENGTH (MPa)			
DAYS	**FOAMED CONCRETE**	**10% PSBE**	**20% PSBE**	**30% PSBE**
28	1.57	7.52	9.43	13.31
60	1.78	7.77	9.75	14.90
90	2.22	8.31	10.76	16.08

	TENSILE SPLITTING STRENGTH (MPa)			
DAYS	**FOAMED CONCRETE**	**10% PSBE**	**20% PSBE**	**30% PSBE**
28	1.42	6.55	8.61	15.16
60	1.70	6.74	9.66	16.69
90	2.07	7.17	10.81	17.46